American Journal of Alternative Agriculture, Volume 17, Number 1, 2002, pp. 41-43.
This article is reprinted with slight modification by the author from "The emperor's new chromosomes" published in *The Land Report*, Number 70, Summer 2001, pp. 6-8. The Land Institute, Salina, Kansas 67401.

The Mirage of Genetic Engineering

by T. S. Cox

The extensive adoption of transgenic plants now underway has provoked heated debate about its effects on human health, rural life, and the environment. But too many critics are neglecting to zero in on transgenic technology's Achilles heel: its inherent inability to deliver on its promises. Longstanding theory and practice predict, and growing evidence confirms, that transgenes cannot dramatically accelerate plant breeding, let alone revolutionize agriculture, save the family farm, or feed the world.

No faster, much costlier

At the 55th Annual Corn and Sorghum Seed Research Conference Proceedings held by the American Seed Trade Association in December of 2000, Drs. Major M. Goodman and Martin L. Carson of North Carolina State University added to the growing evidence that genetic engineering is much more expensive and less effective than plant breeding. They compared corn inbreds that have been produced by two methods: transgene insertion and hybridization between adapted and exotic germplasm.

Corn hybrids grown in the Midwest set new yield records almost every year. But Dr. Goodman has spent the past 25 years demonstrating that there remains much to be gained from the vast array of corn varieties grown across the tropics of Central and South America. He has used them to breed competitive, genetically diverse inbred lines adapted to the United States. His work is considered to be basic research with strictly long-term payoffs.

Goodman and Carson cite the example of NC296, an inbred line adapted to North Carolina but developed from all-tropical parentage. Released in 1990, it has been used to produce commercial hybrids in the United States and at least two other countries. NC296 took 15 years to develop - a long process, typical of breeding that uses exotic germplasm adapted to a different part of the world. It was five more years before hybrids having NC296 as a parent were being grown by farmers.

But compare that with the timetable for a *Bt* corn inbred that carries a bacterial transgene coding for an insecticidal toxin. According to Goodman and Carson, *Bacillus thuringiensis (Bt)* was used as an insecticide by the 1950s. The first gene encoding the *Bt* toxin was cloned by 1981. ... *Bt* gene regulation was known by 1986. ... *Bt* was [inserted] into corn in 1990. ... *Bt* hybrids were first sold in 1997. Because *Bt* was a well-known entity with a long history of use as an "organic" insecticide, little toxicity and allergenicity testing were required for its initial use as a transgene. Even so, its transgenic use took 17 years.

Of course, *Bt* was one of the very first transgenes commercialized. But while advances made in biotechnology over the past two decades may make gene discovery, cloning and transfer marginally faster, they cannot substitute for testcrossing and field testing. No matter how quickly one can carry out laboratory procedures, a certain number of plant generations are needed to accomplish any genetic manipulation, and the life cycles of crop plants can be speeded up only so much. Goodman and Carson list the steps that must occur before a transgenic corn inbred - with a truly novel gene, not just another version of *Bt* - can have its hybrid progeny tested in yield trials:

1. Discovery of the gene.
2. Modification, producing what is known as a "construct" that can be transferred to a new species and, one hopes, perform as expected.
3. Efficacy testing.
4. Transformation of model species.
5. Construct comparison.
6. Transformation of maize plants.
7. Backcrossing the gene into best inbred lines.

These steps occupy nine seasons, more or less. Then, the authors point out, at least as much time is needed to bring the gene to the farmer. That process includes testcrossing to a range of other inbreds, applying for experimental permits, three years of small-plot trials in different hybrid combinations, Environmental Protection Agency clearance, two years of large-plot trials, inbred and hybrid seed production, and sales. Even with the use of winter nurseries in the tropics to achieve two generations per year, and even if no unforeseen delays occur, Goodman and Carson estimate 15 years for development and deployment of a hybrid with a new transgene. This is only slightly shorter than the timetable for developing a hybrid from tropical germplasm through sexual methods - a process that is considered to be long-term, basic research by most corn breeders.

But there is a big difference between the two methodologies: the transgenic hybrid costs at least 25 times as much to develop and release to farmers - 28 times when the current $150,000 in federal permit and clearance fees are figured in. Their million-dollar estimate for discovering a new gene is based on the assumption that discovery is "a one-in-10-year event by a $100,000-a-year postdoc or equivalent (including salary and lab costs.)" In other words, they are assuming that for every ten postdocs or scientists searching for new genes to clone, one gene per year will be discovered and eventually utilized successfully. The authors don't estimate the number of postdocs and scientists worldwide engaged in such activity, but it is huge, with only a handful of commercially useful genes discovered to date. So Goodman and Carson's estimate assumes a steep decrease in future costs of gene discovery. The evolving science of genomics may or may not facilitate the search, but it cannot create genes. And there are not very many genes that, taken individually, will give major improvements in important traits.

One gene vs. many

Even if genetic engineering does not speed up the breeding process, and even if it costs a lot more than sexual methods, it can, admittedly, produce plants with unique traits. *If* the new trait is one that improves the lot of the farmer, and *if* it gives us more or better food on our table, and *if* it protects or restores the rural environment, then something might be accomplished. But the only genes that have been deployed to date are ones that are expected to provide a return on investment for the companies holding patents on the genes or methodologies. There is growing evidence that they have not increased farmers' yields or profits, enhanced food quality or improved the environment. Indeed, transgenic technology - that is, single-gene technology - is not equipped to solve complex problems.

For decades, basic textbooks on plant breeding have included a section on backcross breeding, a traditional technique for moving a gene from Parent No.1 into Parent No. 2 while keeping most of the other thousands of genes of Parent No. 1 intact. Sound familiar? Transgenic technology is just a high-tech form of backcross breeding, the only difference being that it can import genes from more distant branches of the evolutionary tree.

Textbooks also tell us that backcrossing is a useful *adjunct* to a breeding program, but that it is limited to producing updated versions of yesterday's crop varieties - nothing truly new. A different sequence of techniques *has* been producing new crop varieties for over a century:

1. Development of diverse gene pools
2. Recombination to shuffle the entire genetic deck
3. Selection

Sexual recombination in diverse crosses almost always produces some offspring with unexpected expression of traits and unprecedented trait combinations. Breeders must sort through large populations to identify progenies superior to either parent, but the effort is rewarded when unique trait combinations are identified and new varieties developed. Almost all new crop varieties, traditional or modern, have arisen from cycles of hybridization and selection in diverse gene pools, with widespread exchange of seeds, cuttings, tubers, etc. among breeders. Without diversity, recombination and selection, breeding grinds to a halt.

The sacrifice of breeding programs

Genetic engineering is not simply being superimposed on healthy, well-funded breeding programs; it is undermining them. To understand how, consider the economic tradeoff, based on Goodman and Carson's estimates. If it is to produce as many transgenic hybrids as non-transgenic, exotic ones, a breeding program requires a 28-fold increase in funding. (And, even then, the resulting hybrids would embody far less genetic diversity.) That kind of increased investment is rare. More often, 28 non-transgenic hybrids or varieties will be sacrificed to produce one transgenic product. Here, we should quote Goodman and Carson at length:

Once the euphoria over the promise of transgenics fades, the closing of so many quality breeding programs, the loss of valuable sales staff, and the centralization of decision-making at company headquarters are almost certain to be regarded as tragic, even by stockholders interested in short-term profits. There are few good investments that are more long-term than rational plant breeding. Repeated studies have shown that very high returns on investment are available from expenditures on [non-transgenic] breeding ... but the returns are not the instantaneous sort favored by the five-year funding plans currently in vogue. The usefulness of a breeding program is probably more dependent on continuity than ingenuity. The probability of great success by any one breeder is small, but the odds of success of a group of reasonably competent breeders working independently and continuously [and, I might add, sharing seed] is high. At present, the evidence that these same rules apply to biotechnology is almost nonexistent.

The seas of corporate capital on which plant biotechnology has floated for two decades will begin to dry up sooner or later. Genetic engineering is following the trajectory of all the natural and technological wonders that have come and gone in the history of plant breeding. Goodman and Carson listed some past "bandwagons", just in corn breeding: mutagenesis, polyploidy, haploidy, overdominance, harvest index, high lysine, small tassels, nitrogen fixation, nitrate reductase, and somaclonal variation, among others. The heyday of transgenes has lasted a bit longer than most, probably because of its patent potential and the flood of investment that it has brought. Like some of its predecessors, it eventually will find a niche as another tool available to plant breeders. But before its bandwagon rumbles off into the sunset, it will leave a trail of wreckage through our science, our rural environment, and our food supply.

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